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INVESTIGATING APPROPRIATE WATER SYSTEM INNOVATIONS FOR MARGINAL FARMING SYSTEMS IN HILLY WATERSHED OF MAHARASHTRA

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Abstract: *The conventional water resource development model has resulted in the deviation of runoff water away from the hills and mountains communities towards downstream agricultural and urban population. Consequently, the rainfed marginal farming systems in hilly areas are lacking the required water resources due to which the acute water shortage during dry spells and dry seasons results in low yields or crop failure. Providing on-farm rain-runoff water harvesting storages can work like an insurance mechanism increasing the resilience of marginal farmers in hilly areas against the variability of rainfall, allowing them to secure at least one wet season and one dry season crop and an average size animal herd. Investigations were conducted under the RKVY project on "Rain-Runoff Water Harvesting Storage Tanks for Smallholder Farming Systems", M.P.K.V., Rahuri in the hilly watershed at Gadakwadi near Pune (India) to select appropriate Water System Innovations (WSIs) for marginal farming systems. The hydrological potential of various rainwater harvesting systems is estimated in the study area. The diversion farm ponds diverting water from the rivulets are suitable for adaption in midland areas. The elevation difference between the pond and lowland farms allowed irrigation using only the gravity pressure. The rooftop rainwater harvesting system in conjunction with gravity drip irrigation kit and treadle pump is suitable for irrigating vegetable garden of size 1000 m^2 in dry season securing the household nutrition. The WSIs are adequate to meet the annual water demand of marginal farming system. The assessment conducted in the study area indicated that after adaption of WSIs the farming productivity and profitability will be improved doubling the income of marginal farmers.*

Key words: *water harvesting, farming system, hilly area of Maharashtra.*

Introduction

The total number of operational land holding in India is 138.35 million with an average size of 1.15 ha (Anonymous, 2011) out of which 85 percent are in marginal (less than 1 ha) and small farm categories (less than 2 ha). Marginal farming in hilly areas is usually not the focus of national production in terms of quantity, as most of their production is for family consumption; however these farming systems are playing a key role in ensuring household food security. Due to their small scale structure, the marginal farming systems have potential to outperform the large farming systems in terms of farming productivity when the access to productive assets is not constrained. One of the most constraining factors in hilly areas has been the acute water scarcity during dry spells and dry seasons in absence of any water storages.

Usually, in the conventional model of water resources development the rain-runoff water is deviated away from the hills, mountain and sub-mountain communities towards downstream cities and agricultural areas which results in acute water shortage post rainy season. There is potential in the hilly areas to harvest rainwater for irrigation purposes because of availability of suitable landscape. Rainwater harvesting is preferable because of the potentiality of increased production, early recovery cost, low construction cost, high benefit–cost ratio, and easy to use and maintenance

(Domènech et al., 2012; Goel and Kumar, 2005; Oweis and Hachum, 2006; Sultana et al., 2005). By constructing small water reservoirs in upstream midland areas, rainwater can be harvested to irrigate the lowland areas by gravity flow. This strategy can work like an insurance mechanism increasing the resilience of mountain farmers against the variability of the rainfall regimes, securing at least one wet season and one dry season crop along with an average size animal herd. Moreover, farmers will be encouraged to invest more in agricultural inputs and equipment to improve their farming productivity.

Consequently, investigations are conducted in the hilly watershed at *Gadakwadi* near Pune (India) under the RKVY project on "Rain-Runoff Water Harvesting Storage Tanks for Smallholder Farming Systems", M.P.K.V., Rahuri to select appropriate Water System Innovations (WSIs) for marginal farming systems. The aim of this study is to highlight the important role of small water storage structures in marginal and smallholders' livelihoods improvement. Accordingly, the water needs of marginal farming systems towards sustainable crop and livestock production were estimated. The hydrological potential of water harvesting structures in hilly watershed and their feasibility in meeting the water demand of marginal hill farming system were assessed.

Characteristics of hilly marginal farming systems:

The lives and livelihoods of farmers in hilly areas are affected by the same socio-economic changes that affect farmers in the rest of the world, although impacts are often more profound, owing to the increased vulnerability and reduced resilience of hilly farming. These farming systems operate with low external inputs, considering that the marginal farmers often do not have the means, in terms of physical access or finance, to invest in external inputs such as fertilizer, plant and animal protection chemicals and farm machinery. The agricultural and livestock productivity is extremely low. Limited availability of land with low productivity and increasing population pressure are the elements that contribute in increased distress. As a result there is widespread poverty, around 40% of marginal farmers population is food insecure, with half of them suffering from chronic nutrition deficiency.

The RKVY program

The Rashtriya Krishi Vikas Yojana programme namely Rain Runoff Water Harvesting Storages for Smallholder Farming Systems is operated by M.P.K.V., Rahuri in hilly watershed zone near Pune in Maharashtra. The aim of this programme is to highlight the important role of small water storage structures in food security and smallholder's livelihoods improvement. It also aims to propose a set of principles, approaches and measures for the planning, design, construction, and management of small storage structures in light of gathered experience and of the work conducted under the project.

The action plan of the programme includes:

- Construction of rain-runoff water harvesting storages for smallholder farming systems practiced in highland, midland and lowland zone of hilly watershed.
- Adapt suitable irrigation and cultivation methods for efficient use of harvested water (gravity irrigation, zero-electricity pumps, pitcher irrigation, gravity feed drip kit, key-hole garden, tower garden, home garden).
- Achieve diversification in cropping pattern and livestock system maximizing the net benefits for smallholder farmers.

Suitability of *Gadakwadi* watershed for rain-runoff water harvesting:

Gadakwadi watershed is one of the study areas selected for implementation of RKVY program (Fig.1 & Fig.6). *Gadakwadi* is an underdeveloped and remote village situated in *Rajgurunager* tahsil in *Pune* District. The total geographical area of the watershed is 1.5 km^2. Having hilly terrain, this watershed is a narrow north-south strip running through the hilly flank of mountain ranges. The ridgeline surrounding the watershed has altitude ranging from 630 m to 690 m. The ridgeline in the watershed

characteristically represents huge table land with rocky terrain moderately covered with shallow soils and seasonal grasses. In rainy season these vast table land/ highland areas generate large quantities of runoff water which is delivered through rivulets in the low lying areas/ lowlands eroding the soils of productive farms.

The average annual rainfall in the watershed is 700 mm. The distribution of rainfall over the rainy season is as given in Fig.2. The soils are mainly brown to black with varied depth and texture. Total number of households in the village are 151 accounting for the population of 650 farmers as per Census 2011. The literacy rate is 75.65 % compared to 82.34 % of Maharashtra. The total cultivable land in *Gadakwadi* is 100 ha. Agriculture is the main activity in the watershed, accounting for occupation of 99 % families. Only 1% partly depend upon other sources of income, mainly from jobs in the nearby Pune city. The watershed consists of smallholder farmers, most of them are below poverty line. Drinking water is the problem of topmost priority in summer. The average annual income per household is approximately Rs.26,323/- which is slightly more than a dollar per day. Farming and livestock keeping is adapted more as a lifestyle than as a source of income so there is lack of adoption of modern techniques/technologies for increasing production. The farmers cultivate rainfed *bajra*, fodder crops in *Kharif* season and vegetables such as *onion*, *caultiflower*, *cabbage* and *fanugreek* are cultivated in *rabi* season as second crop by some farmers.

Water storages for supplementary/protective irrigation are unavailable. The rainy season starts in June. The crops are generally sown in the first week of June. The watershed has 28 irrigation wells. The water is available in wells from mid July to the end of November. Statistically one dry spell occurs before mid July during which the crop suffer through water stress as water is not available in wells for protective irrigation. Similarly, in *rabi* season the water level in irrigation wells decline significantly as the large quantum of groundwater flow towards the downstream aquifer. The irrigation using groundwater becomes time consuming and difficult as the well water takes long time to recuperate. By the end of December water completely disappears from the irrigation wells.

The farming in *Gadakwadi* needs small water storage structures that can harvest runoff from the rivulets after start of rainy season. These structures will also act as detention ponds further reducing the erosion of lowland farms due to the water discharged by rivulets. After the rainy season the same structures can be used for storing the water pumped from irrigation wells, so that after the groundwater vanishes from the wells at least one or two protective irrigation will be made available in December. Also in summer the farmers can purchase water tankers the water from which can be emptied and stored in these storage structures.

Assessment of water demand of marginal farmers:

Surveys were conducted to understand the water needs of marginal farming systems in *Gadakawadi* towards sustainable crop and livestock production. The marginal farmer is defined as the farmer cultivating agricultural land up to 1 hectare (2.5 acres). The marginal farmers in Gadakwadi require water mainly for the household use, watering of livestock, two protective irrigation in rainy season and four irrigations for second crop in *rabi* season. The water requirement of marginal farmers is estimated and is given below:

- Domestic water for a household of 6 members @15 lpd for 180 days total 16,200 litres.
- Watering 5 cows + 10 goats animals for 180 days, total 50,400 litres
- Two protective irrigations for staple crop using sprinkler irrigation method for 2.5 acre, total 96,000 lits (48,000 lits / irrigation)
- Drip irrigation for 2 acre vegetable, 1 growing season (*Rabi*), total 4,50,000 litres
- Total water requirement of marginal farming system 6,12,600 litres

Rainwater Harvesting for Marginal Farming System:

In order to satisfy the water demand of 612.6 cu.m. per marginal farmer different rain-runoff water harvesting cum irrigation system suitable in bio-physical set up of hilly watershed in *Gadakwadi* zone are studied. The following structures are proposed for construction in *Gadakwadi*.

1. Diversion Farm Pond in midland areas (altitude 630-660m)
2. Rooftop rainwater harvesting system in lowland areas (altitude 600m)

Details of Proposed Technology:

Farm pond irrigation system:

Diversion farm pond lined with HDPE geomembrane plastic paper and having inlet-outlet system are selected to construct. The location for construction is selected in midlands besides the rivulet. In rainy season the water is diverted from rivulets in this farm pond (Fig.3). Diversion channels with stone pitching, sedimentation basin and silt trap will be provided at the inlet to avoid siltation of pond. While selecting the locations for diversion farm pond sufficient elevation difference is kept between the pond and the farms in lowland areas so that the water from pond can be utilized for irrigation using only the gravity pressure. Additionally, the farm pond will have an irrigation outlet which will be operated on the principle of gravity. The irrigation outlet will be connected to the distribution pipeline for applying water to the lowland farms by gravity. Drip irrigation system is provided to each farmer on 1 acre land for efficient utilization of harvested water.

Rooftop Rainwater Harvesting System:

Most of the households in the selected micro-watershed have roofs made up of clay tiles or metal sheets. The rooftop rainwater harvesting system is designed and will be provided suitably for the households. Four interconnected tanks are constructed in situ to store 20 cu.m. harvested rain water (Fig.4).The water will be used mainly for irrigating the vegetable garden in *rabi* season. Gravity drip irrigation system or drip kits consisting of small water storage tank (200 lit) installed on M.S. stand is used for irrigating the vegetable garden (Fig.5). Treadle pump is provided for pumping water from the Ferro-crete tanks in to the raised tank of drip kit. Moreover, simple techniques such as key hole vegetable garden, tower garden, pitcher irrigation, are adopted where use of grey water is made possible.

The water harvesting potential of each structure is estimated (table- 1). As per the water need and potential of water harvesting system the size of diversion farm pond and rooftop RWH system is decided. Diversion farm pond of size 20X20X3 m satisfies the water need of marginal farming system, while rooftop rainwater harvesting system of 20000 liters capacity is sufficient to grow vegetable garden in *rabi* season. The control measures like spreading PET bottles on surface of pond water for reducing evaporation is taken to reduce evaporation losses by 40 % from the farm pond (Simon et. al, 2015).

Gram Sabha was conducted in *Gadakwadi* and eight marginal farmers were selected to experiment the impacts of WSIs selected under this RKVY project (Fig.6). The impact of WSIs such as diversion farm pond, drip irrigation system on 2 acre land, Rooftop RWH system, gravity feed Drip kit and treadle pump on the livelihood of marginal farmers is studied. The cropping pattern of the farmers is improved (table- 2). All farmers are being trained (in 06 training programme) in using the harvested water efficiently. Market linkages are being developed for selling the farm produce. It is expected that the income of each farmer will be increased by Rs.3,00,000/- per annum (90 % confidence level) and the cost of RWH cum irrigation systems can be recovered in 2 to 3 years (table-3).

Conclusions

The diversion farm pond along with drip irrigation system and rooftop RWH along with gravity drip irrigation kit and treadle pump are suitable for adaption in *Gadakwadi* watershed. The on-farm water storage, diversion farm pond has potential to provide two protective irrigations during dry spell, four irrigations in dry season and in

addition satisfy the water needs of average size animal herd and household. The rooftop rainwater harvesting system is useful for the farmers to grow a vegetable garden for the nutrition security of household. From this study it is inferred that during each rainfall event the generated peak runoff can be utilized by the farmers for filling diversion farm ponds, and storage tanks of RWH system. The study shows that in hilly watersheds there is high potential for rainwater harvesting during rainy season and subsequent use of harvested water for gravity-flow lowland irrigation. This improved water supply system can facilitate double to triple cropping system for lowland and permanent horticultural crops in midlands and highlands. Up scaling of these WSIs practices can bring several hilly watersheds in Maharashtra under sustaining cultivation in marginal farming systems improving the livelihood of 65% farmers in the State.

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Table 1: Water harvesting potential of various systems in *Gadakwadi*

System	Micro-Catch-ment area	Runoff Coefficient	Rainfall, M	Runoff Potential, litres	Water Need, litres	Size of structure, m	Storage Capacity, litres	Evp. losses, litres, with control measures	Ultimate Hydrological Potential, litres
Diversion Farm Pond	2 ha	0.3	0.69	42,00,000	6,12,600	20X20X3	11,50,000	3,60,000	7,90,000
Rooftop RWH system	50 m^2	0.8	0.69	28,000	---	4 Ferro-crete tanks each of 5000 lits capacity	20,000	---	20,000

Table 2: Comparison of cropping pattern between sites with and without harvested rainwater irrigation system in the three crop seasons of the year

Without rainwater harvesting facility			With rainwater harvesting facility		
Summer	***Rabi***	***Kharif***	***Summer***	***Rabi***	***Kharif***
Fallow	***Fodder crops:*** *Hy. Napier Lucerne, Maize fodder*	***Staple Crops:*** *Bajra, Tur Maize (Sweet Corn)* ***Fodder crops:*** *Hy. Napier Lucerne, Maize fodder*	***Vegetable crops:*** *Vegetable garden 1000m^2* ***Fodder crops:***	***Staple Crops:*** *Wheat* ***Lentil crops:*** *Gram, Tur , Green Gram, Black Gram* ***Vegetable***	***Staple Crops:*** *Bajra, Maize (sweet corn)* *Oilseed crops: Groundnut* ***Fodder crops:***

			Hy. Napier Lucerne Maize fodder ***Horticultural Crop:*** *Pomegranate*	***crops:*** *Potato, Onion, Brinjal, , Cabbage, Fenugreek Vegetable garden 1000m²* ***Fodder crops:*** *Hy. Napier Lucerne Maize fodder* ***Horticultural Crop:*** *Pomegranate*	*Hy. Napier Lucerne Maize fodder* ***Horticultural Crop:*** *Pomegranate*

Table 3: Yield and economic performance of grain and horticultural crops produced under irrigation with harvested rainwater

Crop	Yield (t/ha)	Net profit, Rs. /ha (mm)
Bajra	2.1	21,000
Maize	2.3	23,000
Wheat	2,3	34,500
Gram	2.13	80,000
Tur	2.03	81,200
Gr. Gram	1.9	76,000
Black gram	1.8	72,000
Pea	1.8	72,000
Potato	26	2,60,000
Onion	2.5	35,207
Tomato	50	39,000
Fenugreek	60000 bundles	55,000
Brinjal	60	70,000
Cabbage	75	1,73,500
Cauliflower	32000 flowers	1,08,500
Pomegranate	5	5,00,000
Average size animal herd	5 cows 10 goats	4,21,500 50,000

Source: http://www.tnau.ac.in/horcbe/tnpfp/economics.pdf

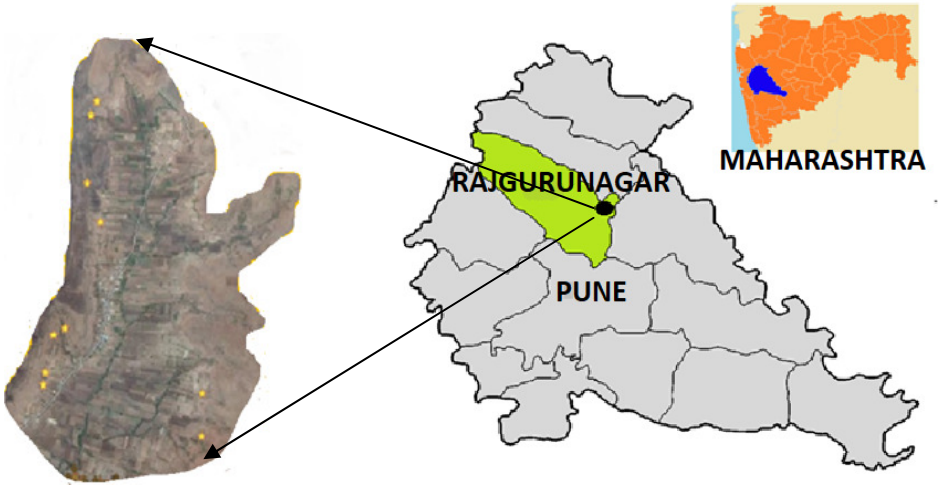

Fig.1: Location Map of *Gadakwadi* Watershed

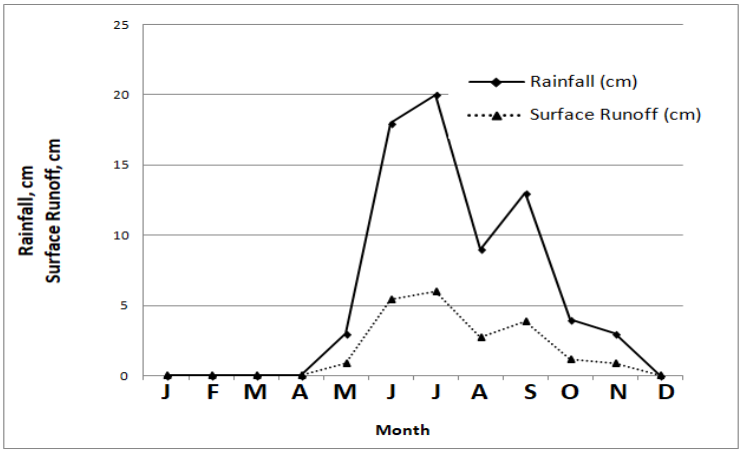

Fig. 2: Rainfall and runoff distribution pattern in study area

Fig.3: Diversion Farm Pond (under construction) in midland area in *Gadakwadi* Watershed

Fig.4: Rooftop rainwater harvesting system with interconnected ferro-crete tanks

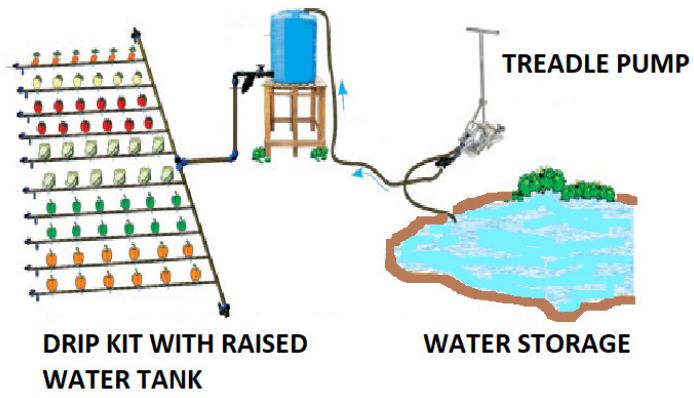

Fig.5: Drip kit with treadle (foot) pump for vegetable garden

Fig.6 Sites selected for Diversion Farm Ponds in midlands if Gadakwadi Watershed